ERDC/CERL TR-00-4

Construction Engineering Research Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Heating, Ventilating, and Air-Conditioning Controls and Related Systems at Antilles High School, Fort Buchanan, Puerto Rico

Condition Assessment Report

Martin J. Savoie, Larry Lister, David M. Schwenk, and Jaynary Barreto

June 2000

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Foreword

This study was conducted for Antilles High School, Fort Buchanan, Puerto Rico, under Military Interdepartmental Purchase Request (MIPR) HEPRAN-99RCL1031, "Condition Assessment and Recommendations for the Replacement of HVAC Controls and Related Systems at Antilles High School, Fort Buchanan, Puerto Rico," dated 9 June 1999. The technical point of contact was Rafael Negron, Facilities Engineer.

The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), U.S. Army Construction Engineering Research Laboratory (CERL). Jaynary Barreto was a student contractor associated with the University of Illinois at Urbana-Champaign. The CERL principal investigator was Martin J. Savoie. The CERL technical editor was William J. Wolfe, Information Technology Laboratory. Larry M. Windingland is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director is Dr. Paul Howdyshell. The Acting Director of CERL is Dr. Alan W. Moore.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Director of ERDC is Dr. James R. Houston and the Commander is COL Robin R. Cababa, EN.

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1 Introduction

Background

The U.S. Army Construction Engineering Research Laboratory (CERL) received a request from the Director of the Antilles Consolidated School System, Fort Buchanan, PR, to provide an independent assessment of the work required to correct problems with overcooling and other temperature control issues at Antilles High School. On 14-16 June 1999, several CERL researchers (Martin Savoie, Dave Schwenk, Larry Lister, and Jaynary Barreto) visited Mr. Rafael Negron at Fort Buchanan to perform a condition assessment at Antilles High School. This report documents the findings of this assessment and recommendations for improvements to the system.

Objectives

The objectives of this work were to perform a "walk-through" assessment of the HVAC system at Antilles High School, to provide a written summary of the system's condition, and to make recommendations for system improvement, including a detailed cost estimate of a system upgrade.

Approach

1. On 14-16 June 1999, CERL researchers visited Antilles High School, Fort Buchanan, PR, to inspect the site's HVAC system.
2. Researchers provided an overview of the system, an assessment of its condition, and detailed recommendations for system improvement (Chapter 2).
3. Since the recommendations for the upgrade included installation of a direct digital control (DDC) system, researchers also provided a brief written discussion of the features of such systems, and the issues one should consider in selecting a DDC system (Chapter 3).
4. Researchers drafted a detailed "Scope of Work" (Chapter 4) to provide Antilles Consolidated School System administration with a complete listing of the tasks required to specify the system upgrade. Researchers also drafted a "Sequence of

Operation" document (Chapter 5) that describes the upgraded system's operation once the work is completed.

5. Researchers also provided a cost estimate for the proposed system upgrade (Appendix).

Mode of Technology Transfer

This information is to be provided directly to the Antilles Consolidated School System. It is also anticipated that this information will be made available through CERL's world-wide web (WWW) at URL:

http://www.cecer.army.mil.

2 Condition Assessment and Recommendations

Introduction

On 14-16 June 1999, Martin Savoie, Dave Schwenk, Larry Lister, and Jaynary Barreto visited Mr. Rafael Negron at Fort Buchanan and performed a condition assessment at Antilles High School. This work was in response to a request from Mr. Negron to provide an independent assessment of the work required to correct problems with overcooling and other temperature control issues at the school. The findings of this condition assessment follow.

Detailed Observations

Systems Description/Overview

Table 1 describes the 12 air-handling units (AHUs) of various sizes at Antilles High School.

Compressed Air Stations and Pneumatic Control Systems

The existing controls are pneumatically operated (Figure 1). Three compressed air stations were inspected, corresponding to AHUs 1 through 9 (Figure 2). None of these stations were functioning. A newer unit was found serving AHUs 7 through 9, but it was not designed to provide 20 psi control air. (It was an industrial-grade 150 psi compressor.)

Table 1. Description of 12 AHUs at Antilles High School.

AHU ID	Zone Served	Size (Type)	Motor hp (not verified)	Notes
AHU-1	NE ground floor classrooms	7,508 (VAV)	7.5	7 terminals
AHU-2	SW ground floor classrooms	5,955 (VAV)	7.5	5 terminals
AHU-3	Administration offices	3,917 (CV)	5	DX* coils, 1 CHW** coil
AHU-4	NE 2nd floor classrooms	9,282 (VAV)	10	8 terminals
AHU-5	SW 2nd floor classrooms	13,505 (VAV)	15	9 terminals
AHU-6	Library	7,505 (CV)	5	DX coils, 1 CHW coil
AHU-7	Cafeteria	6,807 (CV)	7.5	
AHU-8	Drafting	2,612 (VAV)	3	4 terminals; no fan capacity control installed
AHU-9	Shop – not used	1,404	1.5	
AHU-10	Auditorium	12,291 (CV)	10	
AHU-11	Band	3,360 (CV)	3	
AHU-12	Gymnasium	3,283 (CV)	3	

* DX = direct exchange
**CHW = chilled water

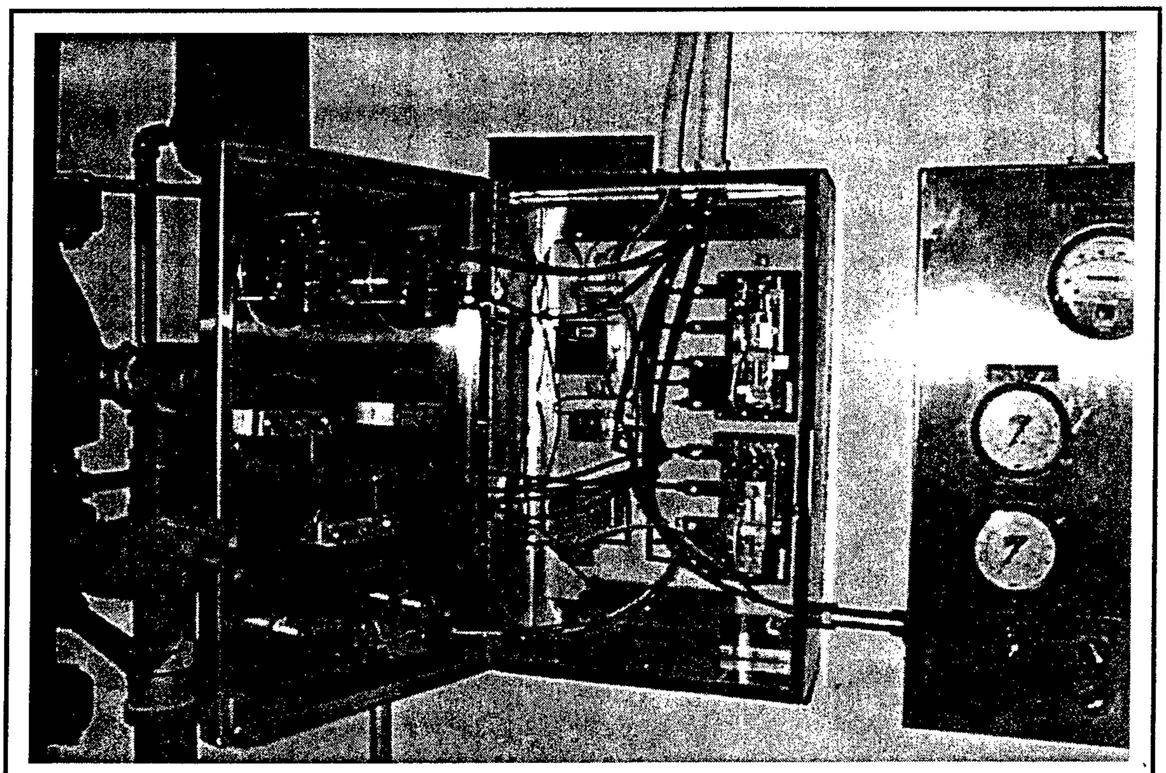

Figure 1. Typical controls cabinet.

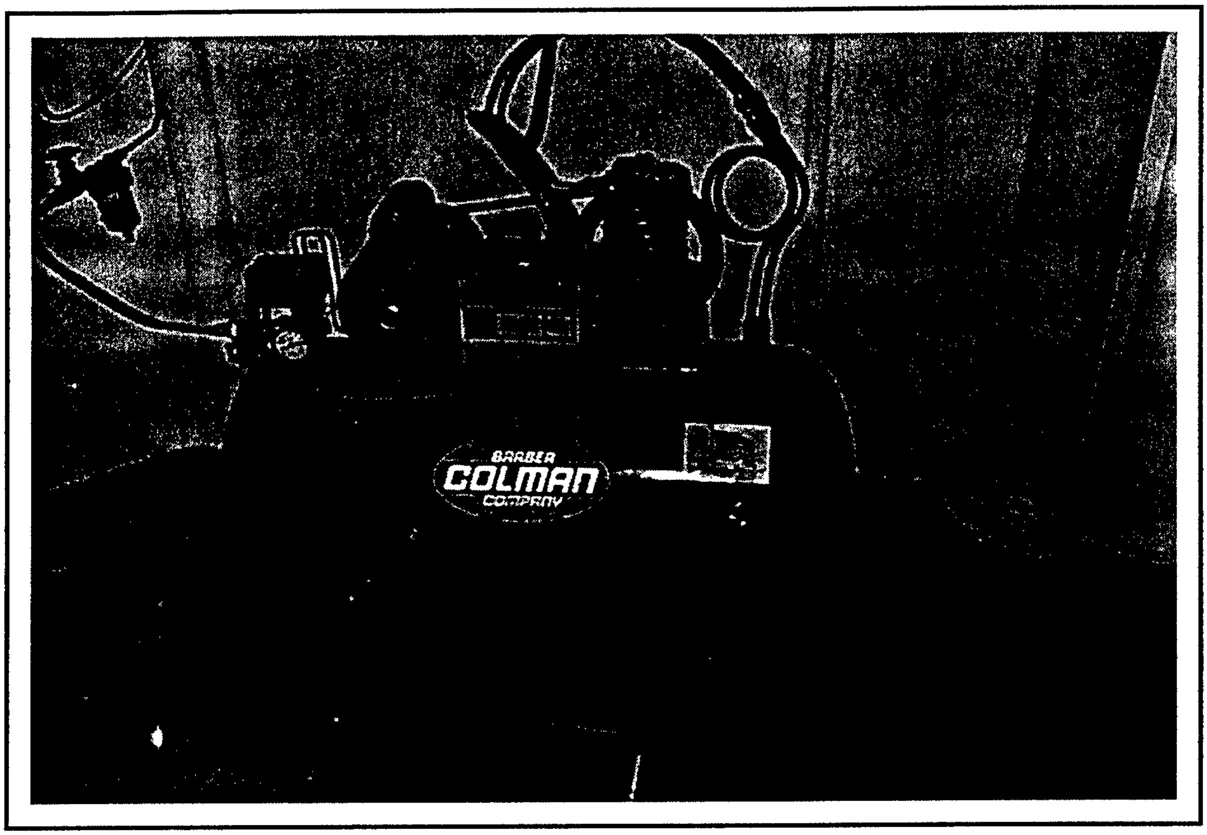

Figure 2. Typical air compressor for controls.

Since none of the air storage tanks had functioning drain valves, they are likely to be full of water. The refrigerated air dryers appeared to be in poor condition. The oil separators appeared not to have been replaced in quite some time. One oil separator was full of water and contained no filter cartridge. The compressed air stations have passed oil (and likely water) to the pneumatic lines and controls throughout the facility. Oil was observed at some of the controllers. Due to contamination, all lines fed by the air compressors must be cleaned, abandoned, or replaced. Cleaning or replacing would likely involve significant expense.

Classroom VAV Air Handling Units (AHUs 1, 2, 4, 5)

All AHUs and associated controls were being operated manually, either at or close to full cooling. Almost all the chilled water valve actuator linkages are disconnected from the valves (Figure 3). All of the inlet guide vane actuators have been disconnected from the guide vanes of the variable air volume (VAV) AHUs. There is no access door to the guide vane actuators. (The front panel of the AHU must be removed to gain access.) As a result, periodic maintenance on the actuators is difficult and has apparently not been performed as often as necessary.

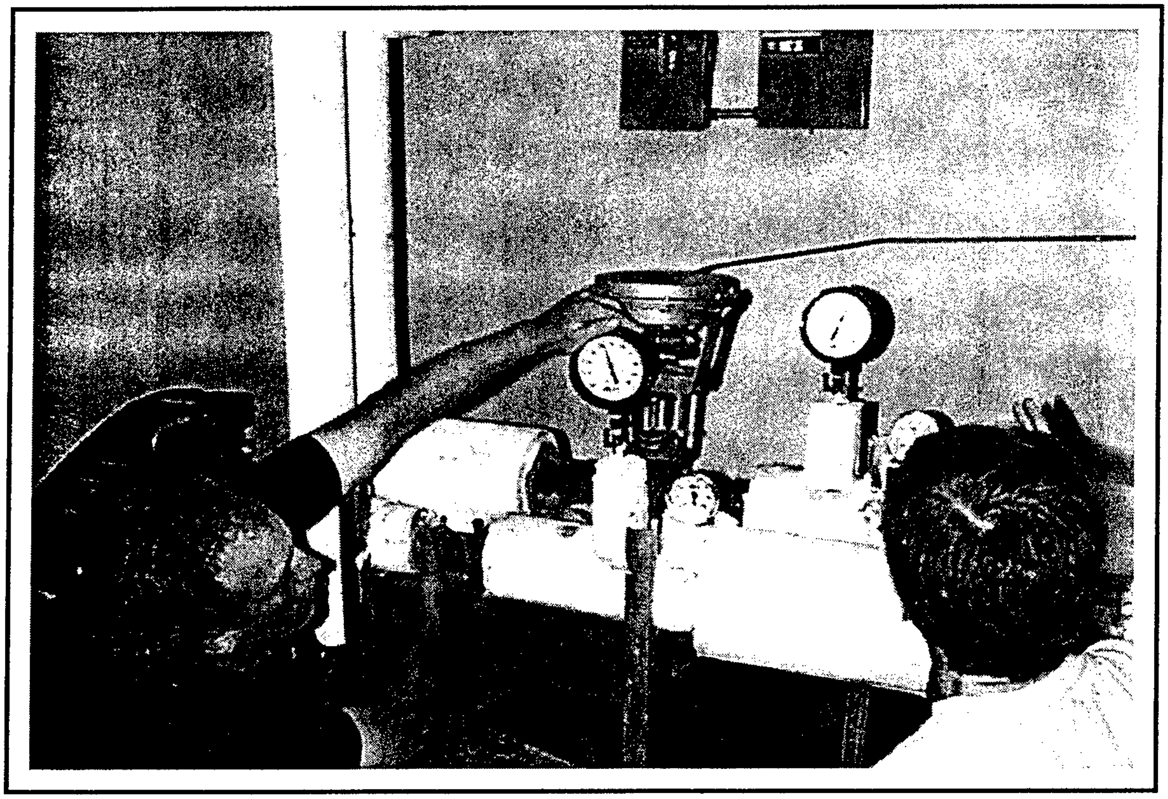

Figure 3. AHU chilled water control valve.

One AHU was inspected closely by removing the access door. This AHU was missing the guide vanes altogether on one side of the dual inlet blower, was missing blades, and had rusted in place on the other side of the blower (Figure 4). The insulation inside this air handler was falling off and should be removed altogether. If removed, the air handler should be insulated on the outside to prevent condensation on the unit. The dampers in several of the air handlers are rusting (Figure 5). The dampers do not need to be modulated, but, should air balancing be required, positioning of the dampers will be difficult. The clean condition of most filters indicates that there was adequate access to the AHU filters to perform periodic maintenance (Figure 6).

Administration Office and Library (AHU-3 and AHU-6)

The CHW valves and DX valves are intended to be controlled based on return air temperature, but the pneumatic controllers are not working. A separate thermostat, as part of field modification, was installed to control the DX unit solenoid valves independent of the CHW valve. Comfort control can be improved by controlling the CHW and DX valves from a single thermostat.

Figure 4. AHU blower corrosion/missing blade.

Auditorium (AHU-10)

When researchers entered the auditorium, they noticed that it was damp and musty-smelling, and that the air handler was not running (and had probably not been run for some time). There was no power to the main AHU disconnect. Also, HVAC controllers had no main air supplied to them. In fact, the main air source lines for the pneumatic control system had been removed. As with a few other systems (dining room and band room), the CHW valve was open, but without air flow, resulting in the formation of condensation on the CHW coil, AHU dampers, and other components and insulation inside the air handler.

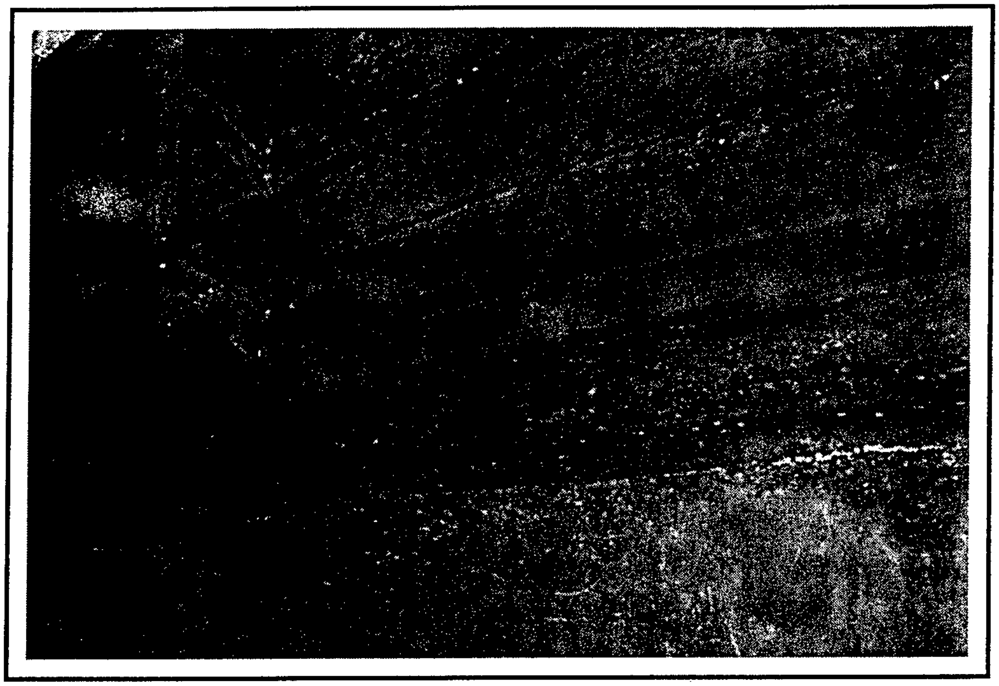

Figure 5. Rusted AHU dampers.

Figure 6. AHU filters.

Cafeteria (AHU-7)

This unit was not running, and was probably shut down for the season. The chilled water valve was disconnected and manually open to full cooling with no air flow, and the coil was wet and dripping.

Detailed Recommendations

Abandon Pneumatic Control and Actuation

Replace all HVAC pneumatic control and actuation with DDC and electric actuation. Abandon and remove (to the extent practical) all pneumatic lines.

Classroom VAV Terminals

Zone temperature control is of primary concern and provides greatest potential for energy savings and improvement in occupant comfort. The existing fan-powered VAV units are manufactured by Trane (VariTrac models) and are configured with pneumatically actuated air-valve volume control (as opposed to blade-style dampers). Trane makes a separate electric damper designed to replace the pneumatic air valve. A DDC network should be used to connect these controls on a common communications bus (1 bus per VAV air handler). Abandon/remove all pneumatic zone temperature controls and actuation. Additional requirements are provided in the Scope of Work.

Classroom VAV AHUs

Replace pneumatic controls with DDC controls, sensors, and electrically actuated CHW valves. Install variable speed drives (VSDs) to provide capacity control. Fit existing CHW valves with electric actuation (if possible) or replace the entire assembly. Relocate duct static pressure tap 75 to 100 percent down the longest duct, or down the duct having the most VAV boxes or most likely to have a constant load. Remove interior insulation in air handlers and replace it with external insulation. Perform maintenance as required to allow for positioning of manual air dampers.

Constant Volume AHUs (Administration, Library, Cafeteria, Auditorium, Band Room)

Replace AHU controllers with DDC control. Replace all CHW valves with electrically actuated valves. Perform maintenance as required to allow for position-

ing of manual air dampers. Install single thermostat in the administration and library zones to sequence and control CHW valve and DX solenoid valves, and provide for start/stop of the remote DX condensing unit.

Seasonal Control Schedule

Once the project is completed, seasonal control (scheduled setback) should be implemented for all zones except administration. Seasonally vacant zones such as the auditorium, library, band room, and drafting area should be minimally conditioned to protect seating, books, electronics, and musical instruments from the effects of humidity.

3 Discussion of DDC System Issues

Improved Operations With DDC

The conversion to a DDC control system will provide a marked upgrade in system functionality over that attainable with pneumatic control. DDC systems provide operators remote access to view existing conditions, change setpoints, and diagnose (and sometimes) fix problems from a workstation or laptop PC. A single operator could monitor many buildings with DDC control, in addition to performing other operations and maintenance (O&M) tasks as well. Energy management and reporting functions can illustrate how efficient operations are resulting in bottom-line operations cost savings. Operational problems can be caught early and fixed before they become larger—and more expensive—problems.

Factors To Be Considered When Selecting a Vendor and Specifying a DDC System

A DDC system involves: (1) microprocessor-based hardware, (2) vendor-specific application software (required to program, monitor, troubleshoot, and report alarms), and (3) a communications network (which can be either system-only or can network many systems from many buildings together). More than 20 HVAC controls manufacturers currently provide a DDC product line. Each is rather unique in its specific approach to DDC. Many vendors systems are incompatible with other vendors, or provide only limited compatibility. Ease of use and system performance can vary dramatically. There are large differences in system flexibility, which may or may not be desirable.

If other schools are going to be upgraded in the future and if a single agency will be responsible for maintaining all Department of Defense Education Activity (DoDEA) schools in Puerto Rico, compatibility between these systems and the need for a consistent system type will become key issues. For these reasons, DoDEA should decide on those attributes of a DDC system most important to their mission and capabilities, both present and future. Some questions include:

- Can the system be upgraded all at once or will it need to be done in phases? (See the Government Cost Estimate for Antilles High School Control System in the Appendix to this report.)

- Will other DDC systems soon need to be installed at other DoDEA schools in Puerto Rico?

- How important is the capability to remotely monitor and troubleshoot the system?

- What is the future for O&M contracting for DoDEA schools? Can those O&M staff be trained?

- Which DDC vendors can provide local support in Puerto Rico?

- What funding mechanisms are available now? What is the potential for additional funding?

- What communications networking currently exists in the schools, and which systems can reside using existing cabling?

4 HVAC Controls System Renovation Guidelines/Scope of Work

Background

The HVAC systems at Antilles High School are in a state of disrepair. The HVAC controls are pneumatic, have failed, and need to be replaced. Pneumatic control failure is due in large part to failure of the compressed air stations and corruption of the pneumatic air lines with oil and water. All pneumatic actuators (chilled water valve and fan inlet guide vane) are not functional, have either broken or disconnected linkages and are, at best, manually positioned. Consequently, the HVAC systems are manually operated in on/off mode to provide either full or no cooling.

Objective

The objective of this project is to replace and commission the Antilles High School HVAC control systems. This includes converting all pneumatic controls and actuators to DDC with electric actuation in 11 AHUs and in the 34 classroom VAV boxes. Note that AHU 9, which is located in the woodshop, is not included in this work.

Requirements

The Contractor shall submit a project bid/proposal by task/line item, with separate bids for each task. The tasks include:

Task 1. VAV Terminal Units 1 Through 34 (in Classrooms)

- Replace VAV box pneumatic air valve with electrically actuated air valve (a conversion valve is available from Trane).
- Remove pneumatic thermostats.
- Install DDC VAV unit controllers.
- Install communications cabling and network all controllers together.

- Execute performance verification test (PVT).
- Provide documentation and training.

Task 2. VAV AHUs 1, 2, 4, and 5 (Serving the Classroom Terminal Units)

- Replace pneumatic chilled water coil valves and actuators with electric chilled water valves and actuators.
- Remove inlet guide vanes, actuators, and linkages.
- Install VSDs for each supply fan motor.
- Remove pneumatic controllers (and any unused enclosures).
- Install DDC system, including controller and sensors.
- Install operator interface device inside each panel.
- Install cabling so that occupant override from any zone thermostat starts AHU fan.
- Remove air compressors and refrigerated air dryers.
- Execute PVT.
- Provide documentation and training.

Task 3. VAV AHU 8 (Serving Drafting/Graphic Arts Classroom Terminal Units)

- Replace pneumatic chilled water coil valves and actuators with electric chilled water valves and actuators.
- Install VSD on the supply fan motor.
- Remove pneumatic controllers (and any unused enclosures).
- Install DDC system, including controller and sensors.
- Install operator interface device inside each panel.
- Install cabling so that occupant override from any zone thermostat starts AHU fan.
- Remove existing air compressor and deliver to DoDEA Facility Engineer.
- Execute PVT.
- Provide documentation and training.

Task 4. Single Zone (Constant Volume) AHUs 3 and 6 (Main Office and Library)

- Replace pneumatic chilled water coil valves and actuators with electric chilled water valves and actuators.
- Remove pneumatic controllers (and any unused enclosures).
- Install DDC AHU controller and sensors.
- Install operator interface device inside each panel.
- Install cabling so that occupant override starts AHU fan.
- Execute PVT.
- Provide documentation and training.

Task 5. Single Zone (Constant Volume) AHU 7 (Serving the Cafeteria)

- Replace pneumatic chilled water coil valve and actuator with electric chilled water valve and actuator.
- Remove pneumatic controllers (and any unused enclosures).
- Install DDC AHU controller and sensors.
- Install operator interface device inside each panel.
- Install cabling so that occupant override starts AHU fan.
- Execute PVT.
- Provide documentation and training.

Task 6. Single Zone (Constant Volume) AHU 10 (Serving the Auditorium)

- Replace pneumatic chilled water coil valve and actuator with electric chilled water valve and actuator.
- Remove pneumatic controllers (and any unused enclosures).
- Install DDC AHU controller and sensors.
- Install operator interface device inside each panel.
- Install cabling so that occupant override starts AHU fan.
- Execute PVT.
- Provide documentation and training.

Task 7. Single Zone (Constant Volume) AHU 11 (Serving the Band Room)

- Replace pneumatic chilled water coil valve and actuator with electric chilled water valve and actuator.
- Remove pneumatic controllers (and any unused enclosures).
- Install DDC AHU controller and sensors.
- Install operator interface device inside each panel.
- Install cabling so that occupant override starts AHU fan.
- Execute PVT.
- Provide documentation and training.

Task 8. Single Zone (Constant Volume) AHU 12 (Serving Gym Offices)

- Replace pneumatic chilled water coil valve and actuator with electric chilled water valve and actuator.
- Remove pneumatic controllers (and any unused enclosures).
- Install DDC AHU controller and sensors.
- Install operator interface device inside each panel.
- Install cabling so that occupant override starts AHU fan.
- Execute PVT.
- Provide documentation and training.

Task 9. Communications Network

- Install cabling and network communications devices to interface each AHU controller and the VAV terminal unit controllers with a remotely located operator workstation (OWS).
- Install remotely located OWS in building 566.
- Install OWS graphical user interface (GUI) software.
- Execute PVT.
- Provide documentation and training.

Task 10. Insulate Air Handlers

- Remove insulation from interior of all AHU fan cabinets.
- Install insulation on exterior of all AHU fan cabinets.

Submittals

Points of Contact

The Contractor shall deliver two copies of each submittal to each of the addressees shown below for a total of four copies. Quantities of the "Training Material" submittal shall be as shown under "Training Materials." Table 2 lists submittal due dates.

Mr. Rafael Negron (2 copies)
Facility Engineer
Antilles Consolidated School System (ACSS)
Building 566
Fort Buchanan, PR 00934

Mr. Larry Lister (2 copies)
Construction Engineering Research Laboratory
Facilities Division – Energy Branch
2902 Newmark Dr.
Champaign, IL 61822-1076

Table 2. Submittal list and due date.

Submittal	Due
Schedule	1 month after award of contract
Engineering drawings	1 month after award of contract
Equipment data	1 month after award of contract
Software and firmware documentation	As agreed and government approved
Software	As agreed and government approved
As-built drawings	As agreed and government approved
PVT certification and notification	2 weeks prior to PVT
Training schedule	2 weeks prior to training as agreed and government approved
Training materials	At training
Record of warranty	As agreed and government approved

Schedule

The Contractor shall submit a construction schedule showing all submittals, completion of each of 10 tasks, performance verification test (PVT), and training. The Contractor shall submit an updated schedule should the schedule change during the project.

Engineering Drawings

The Contractor shall submit a set of engineering drawings including:

- Riser diagram showing all DDC controllers and interface devices, all communications cabling, and network interface devices. Each controller/device shown on the riser diagram shall include a room number location.
- Sequence of operation of the format and content of the specified Sequences of Operation.
- Control diagram, which shall be a one-line ducting arrangement for each HVAC system labeling and showing all controllers, controlled equipment and devices, control input/output points, and instrumentation.
- Equipment layout drawing (or narrative), showing (describing) the location for each contractor supplied enclosure, non-enclosed controller, and VSD. (In other words, the Contractor shall specify where each piece of equipment is going to be located/installed.) The Contractor shall show labeling of each device on the drawing/narrative.
- Wiring and termination diagram showing each piece of control hardware and all wiring terminations including wire labels.

Equipment Data

The Contractor shall provide equipment data for each piece of installed hardware showing hardware specifications. The data shall be in booklet form with a table of contents showing the name of each piece of equipment and its complete part number.

Software

The Contractor shall provide original licensed copies of all operating and configuration software programs that can be used on two computers: one desktop PC operator workstation, and one field workstation (laptop PC). The Contractor shall provide copies of all software databases and configuration settings specific to this project. The Contractor shall provide full software and firmware documentation including operator manuals. The Contractor shall provide one copy of software to CERL for temporary use prior to and during commissioning. This

copy will be returned to the Contractor after commissioning or purchased by CERL.

As-Built Drawings

The Contractor shall provide a final as-built set of Engineering Drawings.

PVT Certification and Notification

The Contractor shall provide written certification that the system is ready for government witnessing of the PVT.

Training Schedule

The Contractor shall provide a training schedule and agenda.

Training Materials

The Contractor shall provide three sets of training materials at the beginning of training. The training materials shall minimally consist of as-built drawings, equipment data, and an Operator Interface Device (OID) operators manual. OWS training materials shall also include operator and programming manuals.

Record of Warranty

The Contractor shall provide certification of the 1-year warranty.

Products

DDC Control Units

Controllers shall have input/output (I/O) and computational capacity to perform the specified sequences of operation and shall support the specified communications and supervisory control functions.

Standard/Open Protocol

It is preferred (but not required) that communication between DDC system components use native BACnet or LONTalk protocols for future compatibility with other systems and components.

Electric Air Valves

There are 34 VAV boxes, each containing a pneumatic air valve as shown in original system design drawing ACV-12. The Contractor shall replace each pneumatic air valve with a Trane electric air valve as shown in Table 3. For each air valve, the replacement shall occur at the same time as installation of the new digital controller and thermostat so as to minimize VAV box downtime. "Box Type" is as shown on the original system design drawings (NAVFAC construction contract N 62470-04-B-4345). The original drawings show "B" type boxes in rooms 105 and 112, but visual inspection revealed that these are "C" type boxes. Therefore, there appear to be no "B" type boxes. Confirmation of all VAV box types is the responsibility of the Contractor.

Table 3. Pneumatic to electric air valve replacement list.

Trane VAV box	Box Type	Electric Air Valve Part No.	List price*
VFCD-0607	A	VAL2747	$309.25
VFCD-1107	C	VAL2748	$301.20
VFCD-1711	D	VAL2749	$311.50
VFCD-2420	E	VAL2750	$348.90
* List prices shown here are for guidance only and are with no discount multiplier applied.			

Variable Speed Drive

Each VAV air handler supply fan shall have a fully configured VSD installed. Each VSD shall be selected to be compatible with the existing fan motor and shall meet the specified functional requirements. Each VSD shall have a built-in visual display and keypad. VSDs must be located in an environment compatible with VSD manufacturers specifications.

Current Sensing Relay (CSR) and Switch

Each AHU shall have a CSR to sense fan status and to energize the fan motor starter. Each CSR shall also be of the type that senses a broken or missing fan belt.

Temperature Sensor

Temperature sensor elements shall be nickel, platinum, or Balco. Discharge air temperature sensors (located downstream from coils) shall be averaging type.

Thermostats

Thermostats shall have an adjustable setpoint, local temperature display or thermometer, unoccupied mode override switch, and communications jack for connection of field workstation.

Electric Valve Actuator

All chilled water valves shall be of the electrically actuated modulating type. Electric actuator torque shall be comparable to the torque of the existing pneumatic valve actuators and shall provide complete shutoff of the valve. Replacement valve flow coefficients shall be comparable to those of the existing valves.

Cable and Wire

Cable and wiring installed in plenums shall be plenum-rated. Sensor cable and wire in mechanical rooms shall be installed in conduit.

Warranty

The Contractor shall provide a 1-year warranty on all products and work.

Execution

Schedule

All work shall be done during non-school hours except as otherwise authorized.

Control Programming

The Contractor shall install, configure, program, calibrate, and adjust all controllers, operator interfaces, sensors, actuators, network communication devices, and the operator workstation to perform as specified and in accordance with the manufacturer's ordinary functionality.

VAV Terminal Unit Schedules

For each VAV box controller and thermostat, the Contractor shall set the initial zone setpoint, VAV box minimum flow, and re-circulation fan "on" temperature as described in the sequence of operation and shown in the VAV box schedule.

Operator Workstation PC

The Contractor shall install, program, and configure the workstation hardware and software to display a graphic for each AHU and graphic or pop-up screen for each VAV box. Each graphic and pop-up screen shall provide real-time display of all I/O points and alarms associated with that AHU/VAV box. The Contractor shall also configure the workstation software to provide a visual representation of the associated floor plans and zones showing zone temperature, airflow, set-point, and fan status.

Operator Interface Device

Each controller shall have a local OID permanently mounted inside the control panel enclosure. Each OID shall be programmed/configured to display each set-point, I/O point value, and permit on/off control of the fan.

Enclosures

Each AHU controller shall be mounted in an enclosure. Each enclosure shall be in the same mechanical room as the equipment it serves (except the controllers for AHUs 3 and 6, which shall be in the same mechanical room where the existing controllers are located).

Labeling

All wiring terminations shall be labeled as shown on the government-approved Wiring and Termination Diagram drawing. All enclosures/devices shall be labeled as shown in the government-approved Equipment Layout drawing.

Performance Verification Test

The Contractor shall execute a government witnessed PVT on the control systems and network. The PVT shall demonstrate that each control system performs according to the specified sequence of operation and that the operator interface devices, the communications network, and operator workstation function as specified. The Contractor shall notify the government in advance of the PVT as shown in Table 1. The intent is to perform a single PVT after all controllers, network, and systems are functional and ready for testing.

Trash

The Contractor shall dispose of all removed hardware and unused construction materials.

Training

The Contractor shall provide:

1. One day of DDC controls training for up to three persons on O&M of the DDC controls. This training shall include a detailed description of all as-built drawings, review of the equipment data sheets, demonstration of how to operate the controller OID, description of each air handler's sequence of operation, location of all sensors, controllers, and controlled devices.
2. Two half-days of training for up to three persons on operation and programming of the operator workstation.

Completion Date

All work shall be completed by: ______________________.

5 Sequence of Operation

AHUs 1, 2, 4, and 5

The supply fan shall be started and stopped from a hand-off-auto switch as follows:

AUTO: Fan shall start and stop from a direct digital controller (DDC) digital output applied to the start/stop input at the fan VSD. The DDC shall control the fan start/stop based on an operator adjustable schedule. Pressing the override button at any zone thermostat shall temporarily override the schedule and shall turn the supply fan on for a period of 1 hour.

HAND: Fan shall start.

OFF: Fan shall stop.

The supply fan variable speed drive (VSD) unit shall generate a fan on/off status input to the DDC.

Discharge air temperature, as sensed at the element located downstream of the cooling coil shall be maintained at an operator adjustable setpoint of 55 °F by modulating the normally closed chilled water coil value. When the supply fan is off, as sensed by the CSR, the chilled water valve shall close.

Return air temperature, as sensed at the element located in the return air duct, shall be used only as a monitoring point.

Duct static pressure, as sensed at the sensing tip located down the duct as indicated on the original design drawings shall be maintained at an operator adjustable setpoint of 1 inch water column (iwc) by modulating the fan VSD.

The smoke detector in the supply air shall de-energize the supply fan upon activation. An existing smoke detector interface activates the building fire alarm system.

The DDC shall be installed in an enclosure. A local OID shall be permanently mounted inside each enclosure.

The DDC shall transmit alarms to the Operator Workstation when:

- the fan on/off status conflicts with fan start/stop command
- the return air temperature rises above 78 °F
- the smoke alarm is triggered.

AHUs 3 and 6

The supply fan shall start and stop from a hand-off-auto switch as follows:

AUTO: Fan shall start and stop from a DDC digital output through a CSR switch contact at the fan motor starter. The DDC shall control the fan start/stop based on an operator adjustable schedule. Pressing the override button at the zone thermostat shall temporarily override the schedule and shall turn the fan on for a period of 1 hour.

HAND: Fan shall start.

OFF: Fan shall stop.

The CSR shall be attached to one leg of the supply fan three-phase power and shall generate a fan on/off status input to the DDC. When the supply fan is off, as sensed by the CSR, the chilled water valve shall close, the condensing unit shall be off, and condensing unit valves shall close.

The condensing unit, for the direct expansion cooling coil, shall start and stop from a hand-off auto switch as follows:

AUTO: The condensing unit shall start from a DDC digital output when the space temperature, after a 2-minute delay, rises 3 °F above the space thermostat setpoint.

HAND: The condensing unit shall start.

OFF: The condensing unit shall stop.

Space temperature, as sensed at the space thermostat, shall be maintained at the space thermostat setpoint. The AHU-3 thermostat shall be located in the open area behind the reception counter. AHU-6 thermostat shall be located in the large open area near the office (that is below the air handler). Upon a rise in space temperature, the normally closed chilled water coil value shall be modulated toward open first, and then, if the temperature continues to rise, and the condensing unit is "on," the solenoid valve(s) shall open in sequence.

Return air temperature, as sensed at the element located in the return air duct, shall be used only as a monitoring point.

The smoke detector in the supply air shall de-energize the supply fan upon activation. An existing smoke detector interface activates the building fire alarm system.

The DDC shall be installed in an enclosure. A local OID shall be permanently mounted inside each enclosure.

The DDC shall transmit alarms to the Operator Workstation when:

- the fan on/off status conflicts with fan start/stop command
- the return air temperature rises above 78 °F
- the smoke alarm is triggered.

AHUs 7, 8, 9, 10, 11, and 12

The supply fan shall start and stop from a hand-off-auto switch as follows:

AUTO: Fan shall start and stop from a DDC digital output through a CSR switch contact at the fan motor starter. The DDC shall control the fan start/stop based on an operator adjustable schedule. Pressing the override button at the zone thermostat shall temporarily override the schedule and shall turn the fan on for a period of 1 hour.

HAND: Fan shall start.

OFF: Fan shall stop.

The CSR shall be attached to one leg of the supply fan three-phase power and shall generate a fan on/off status input to the DDC. When the supply fan is off, as sensed by the CSR, the chilled water valve shall close.

Space temperature, as sensed at the space thermostat, shall be maintained at the space thermostat setpoint by modulating the normally closed chilled water valve. The thermostat shall be located in the largest open space served by the AHU. The auditorium thermostat shall be located toward the back of the auditorium.

Return air temperature, as sensed at the element located in the return air duct, shall be used only as a monitoring point.

The smoke detector in the supply air shall de-energize the supply fan upon activation. An existing smoke detector interface activates the building fire alarm system (except AHU-9).

The DDC shall be installed in an enclosure. A local OID shall be permanently mounted inside each enclosure.

The DDC shall transmit alarms to the Operator Workstation when:

- the fan on/off status conflicts with fan start/stop command
- the return air temperature rises above 78 °F
- the smoke alarm is triggered.

VAV Terminal Units

Each fan powered VAV terminal unit shall be provided with a room thermostat and DDC flow controller to modulate the unit air valve to maintain room temperature. Minimum and maximum unit cfm flow setpoints shall be set as shown in the original system design drawings (NAVFAC construction contract N 62470-04-B-4345). Flow setpoints shall have a deadband setting of no less than 50 cfm. Temperature throttling range shall be set to 6 °F. Room thermostat shall have a temperature setpoint adjustment, temperature display, an override button, and communications jack. The override button shall override the scheduled "off" time by starting the AHU supply fan. The fan shall run for a period of 1 hour. The override period shall be operator adjustable. The unit fan shall be wired for control and the unit DDC controller shall be capable of controlling the fan using the standard logic of the DDC controller, but the control logic shall be overridden to keep the fan off.

6 Summary

Condition Assessment

The HVAC equipment is generally well-designed and is appropriate for the intended application. The equipment appears to have adequate if not excess capacity to handle the cooling loads under proper control. However, much of the equipment is rusting and has degraded significantly, especially those parts of the equipment that are controller-actuated. All of the HVAC controls are pneumatic and have failed. The air compressors are not running, and the pneumatic lines are fouled with oil, dirt, and water. The vast majority of the actuated devices (valves and inlet guide vanes) have broken or disconnected linkages and are, at best, manually positioned. As a result the HVAC systems are operated in an "on/off" mode to provide full or no cooling. The recent proposal to replace the Antilles High School HVAC control system was also reviewed in a meeting with the proposing Contractor during our site visit. The proposal was thorough in the number and type of controls to be replaced, but did not include the need to also replace pneumatically actuated equipment such as control valves and dampers with new electrically actuated devices.

Recommendations

It is recommended that the DoDEA replace the pneumatic control system at Antilles High School with a new DDC system. Replacement of actuated devices, including control valves and inlet guide vanes (the latter with VSDs) must be included. Further, it is strongly recommended that the system be designed and specified carefully by DoDEA to:

1. Ensure compatibility with existing maintenance practices.
2. Ensure that all necessary DDC functions deemed useful to DoDEA are included (e.g., such as energy management, reporting, alarming, diagnostics, and remote operating capability).
3. Take into account future network expansion to other DoDEA schools in Puerto Rico.

Because this problem is common in schools throughout the United States, it is further recommended that DoDEA consider developing a DDC-based HVAC controls specification that can be used for other DoDEA facilities.

Appendix: Cost Estimates

The following pages show calculated cost estimates to renovate the HVAC system at the Antilles Consolidated School System.

Fort Buchanan Antilles High School DDC Upgrade Cost Estimate
7/12/1999

	Hardware				Technician			Manager/Engineer			
	cost ea.	qty	total	labor hrs	hrs	$/hr	labor $	hrs	$/hr	labor $	Total
Task 1. VAV terminal units 1 thru 34 (In classrooms)											
Replace VAV box pneumatic air valve with electric air valve	$260	34	$8,840	5	170	$50	$8,500	17.0	$75	$1,275	$18,615
Remove pneumatic thermostats		34	$0	1	34	$50	$1,700	3.4	$75	$255	$1,955
Install DDC VAV unit controllers											
stat & cable	$31	34	$1,054	2	68	$50	$3,400	6.8	$75	$510	$4,964
volume controller	$205	34	$6,970	4	136	$50	$6,800	13.6	$75	$1,020	$14,790
setup/programming		34		0.5	17	$50	$850	1.7	$75	$128	$978
misc hardware	$10	34	$340	0.5	17	$50	$850	1.7	$75	$128	$1,318
Install comm. cabling and network all controllers together											
Belden	$500	1	$500	16	16	$50	$800	1.6	$75	$120	$1,420
Execute performance verification test (PVT)		34	$0	0.5	17	$50	$850	1.7	$75	$128	$978
Provide documentation and training											
design/drafting		1		8	8	$50	$400	16.0	$75	$1,200	$1,600
copying/duplication	$100	1	$100	1	1	$30	$30	0.1	$75	$8	$138
prep for training		1	$0	8	8	$50	$400	0.8	$75	$60	$460
training		1		4	4	$50	$200	0.4	$75	$30	$230
Task Totals:			$17,804		496		$24,580	65		$4,830	**$47,214**

Task 2. VAV AHUs 1,2,4,&5 (Serving classroom units)											
Replace pneumatic CHW coil valves/actuators with electric	$425	4	$1,700	6	24	$50	$1,200	2.4	$75	$180	$3,080
Remove inlet guide vanes, actuators, and linkages		4		2	8	$50	$400	0.8	$75	$60	$460
Install variable speed drives for each supply fan motor	$1,500	4	$6,000	12	48	$50	$2,400	4.8	$75	$360	$8,760
Remove pneumatic controllers (and any unused enclosures)		4		5	20	$50	$1,000	2.0	$75	$150	$1,150
Install DDC system, including controller, sensors, and cabling											
enclosure	$75	4	$300	2	8	$50	$400	0.8	$75	$60	$760
operator interface display device	$336	4	$1,344	1	4	$50	$200	0.4	$75	$30	$1,574
controller	$500	4	$2,000	8	32	$50	$1,600	3.2	$75	$240	$3,840
I/O hardware:											
AI: RAT point sensor	$24	4	$96	0.5	2	$50	$100	0.2	$75	$15	$211
AI: DAT averaging sensor	$90	4	$360	1	4	$50	$200	0.4	$75	$30	$590
AI: Duct static DP sensor	$200	4	$800	0.5	2	$50	$100	0.2	$75	$15	$915
AO: VFD and CHW valve		8	$0	0	0	$50	$0	0.0	$75	$0	$0
DI and DO: VSD I/O (Fan status & S/S)		4	$0	0	0	$50	$0	0.0	$75	$0	$0
DI: smoke & fire		8	$0	0	0	$50	$0	0.0	$75	$0	$0
sensor/actuator cabling/conduit	$25	32	$800	1.5	48	$50	$2,400	4.8	$75	$360	$3,560
actuators											
comm. cabling (tstat to AHU S/S)	$25	4	$100	4	16	$50	$800	1.6	$75	$120	$1,020
setup/programming		4	$0	2	8	$50	$400	0.8	$75	$60	$460
misc. hardware	$50	4	$200	1	4	$50	$200	0.4	$75	$30	$430
Remove air compressors and refrigerated air dryers		2	$0	3	6	$50	$300	0.6	$75	$45	$345
Execute performance verification test (PVT)		4	$0	0.5	2	$50	$100	0.2	$75	$15	$115
Provide documentation and training		4	$0	0.5	2	$50	$100	0.2	$75	$15	$115
design/drafting		1		8	8	$50	$400	8.0	$75	$600	$1,000
copying/duplication	$100	1	$100	1	1	$30	$30	0.1	$75	$8	$138
prep for training		1	$0	8	8	$50	$400	0.8	$75	$60	$460
training		1		4	4	$50	$200	0.4	$75	$30	$230
Task Totals:			$13,800		259		$12,930	33		$2,483	**$29,213**

Task 3. VAV AHU 8 (Serving Drafting/Graphic arts units)											
Replace pneumatic CHW coil valves/actuators with electric	$425	1	$425	6	6	$50	$300	0.6	$75	$45	$770
Install variable speed drive on the supply fan motor	$1,500	1	$1,500	12	12	$50	$600	1.2	$75	$90	$2,190
Remove pneumatic controllers (and any unused enclosures)		1		5	5	$50	$250	0.5	$75	$38	$288
Install DDC system, including controller, sensors, and cabling											
enclosure	$75	1	$75	2	2	$50	$100	0.2	$75	$15	$190
operator interface display device	$336	1	$336	1	1	$50	$50	0.1	$75	$8	$394
controller	$500	1	$500	8	8	$50	$400	0.8	$75	$60	$960
I/O hardware:											
AI: RAT point sensor	$24	1	$24	0.5	0.5	$50	$25	0.1	$75	$4	$53
AI: DAT averaging sensor	$90	1	$90	1	1	$50	$50	0.1	$75	$8	$148
AI: Duct static DP sensor	$200	1	$200	0.5	0.5	$50	$25	0.1	$75	$4	$229
AO: VFD and CHW valve		2	$0	0	0	$50	$0	0.0	$75	$0	$0
DI and DO: VSD I/O (fan status & S/S)		1	$0	0	0	$50	$0	0.0	$75	$0	$0
DI: smoke		1	$0	0	0	$50	$0	0.0	$75	$0	$0
sensor/actuator cabling/conduit	$25	7	$175	1.5	10.5	$50	$525	1.1	$75	$79	$779
actuators											
comm. cabling (tstat to AHU S/S)	$25	1	$25	4	4	$50	$200	0.4	$75	$30	$255
setup/programming		4	$0	2	8	$50	$400	0.8	$75	$60	$460
misc. hardware	$50	4	$200	1	4	$50	$200	0.4	$75	$30	$430
Remove existing air compressor and deliver to DoDEA Facility Engineer		1	$0	3	3	$50	$150	0.3	$75	$23	$173
Execute performance verification test (PVT)		1	$0	0.5	0.5	$50	$25	0.1	$75	$4	$29
Provide documentation and training											
design/drafting		1		2	2	$50	$100	4.0	$75	$300	$400
copying/duplication	$100	1	$100	0.1	0.1	$30	$3	0.0	$75	$1	$104
prep for training		1	$0	4	4	$50	$200	0.4	$75	$30	$230
training		1		2	2	$50	$100	0.2	$75	$15	$115
Task Totals:			$3,650		74		$3,703	11		$841	$8,194

Task 4. Single zone AHUs 3 and 6 (Main office & library)											
Replace pneumatic CHW coil valves/actuators with electric	$425	2	$850	6	12	$50	$600	1.2	$75	$90	$1,540
Remove pneumatic controllers (and any unused enclosures)		1		5	5	$50	$250	0.5	$75	$38	$288
Install DDC system, including controller, sensors, and cabling											
enclosure	$75	2	$150	2	4	$50	$200	0.4	$75	$30	$380
operator interface display device	$336	2	$672	1	2	$50	$100	0.2	$75	$15	$787
controller	$500	2	$1,000	8	16	$50	$800	1.6	$75	$120	$1,920
I/O hardware:											
AI: RAT point sensor	$24	2	$48	0.5	1	$50	$50	0.1	$75	$8	$106
AI: CHW sensor	$24	2	$48	0.5	1	$50	$50	0.1	$75	$8	$106
AI/DI: Space tstat	$26	2	$52	1	2	$50	$100	0.2	$75	$15	$167
AO: CHW valve		2	$0	0	0	$50	$0	0.0	$75	$0	$0
DI and DO: Fan status & S/S CSR	$75	2	$150	0.5	1	$50	$50	0.1	$75	$8	$208
DO: liquid line solenoid valve relays	$25	4	$100	0	0	$50	$0	0.0	$75	$0	$100
DI: smoke		2	$0	0	0	$50	$0	0.0	$75	$0	$0
sensor/actuator cabling/conduit	$25	16	$400	1.5	24	$50	$1,200	2.4	$75	$180	$1,780
actuators											
comm. cabling (tstat to AHU S/S)	$25	1	$25	4	4	$50	$200	0.4	$75	$30	$255
setup/programming		1	$0	2	2	$50	$100	0.2	$75	$15	$115
misc. hardware	$100	2	$200	1	2	$50	$100	0.2	$75	$15	$315
Remove existing air compressor and deliver to DoDEA Fac Engr		0	$0	3	0	$50	$0	0.0	$75	$0	$0
Execute performance verification test (PVT)		2	$0	0.5	1	$50	$50	0.1	$75	$8	$58
Provide documentation and training											
design/drafting		1		2	2	$50	$100	4.0	$75	$300	$400
copying/duplication	$100	1	$100	0.1	0.1	$30	$3	0.0	$75	$1	$104
prep for training		1	$0	4	4	$50	$200	0.4	$75	$30	$230
training		1		2	2	$50	$100	0.2	$75	$15	$115
Task Totals:			$3,795		85		$4,253	12		$923	**$8,971**

Task 5. Single zone AHU 7 (Serving the Cafeteria)											
Replace pneumatic CHW coil valves/actuators with electric	$425	1	$425	6	6	$50	$300	0.6	$75	$45	$770
Remove pneumatic controllers (and any unused enclosures)		1		5	5	$50	$250	0.5	$75	$38	$288
Install DDC system, including controller, sensors, and cabling											
enclosure	$75	1	$75	2	2	$50	$100	0.2	$75	$15	$190
operator interface display device	$336	1	$336	1	1	$50	$50	0.1	$75	$8	$394
controller	$500	1	$500	8	8	$50	$400	0.8	$75	$60	$960
I/O hardware:											
AI: RAT point sensor	$24	1	$24	0.5	0.5	$50	$25	0.1	$75	$4	$53
AI/DI: Space tstat	$26	1	$26	1	1	$50	$50	0.1	$75	$8	$84
AO: CHW valve		1	$0	0	0	$50	$0	0.0	$75	$0	$0
DI and DO: Fan status & S/S CSR	$75	1	$75	0.5	0.5	$50	$25	0.1	$75	$4	$104
DI: smoke		1	$0	0	0	$50	$0	0.0	$75	$0	$0
sensor/actuator cabling/conduit	$25	5	$125	1.5	7.5	$50	$375	0.8	$75	$56	$556
actuators											
comm. cabling (tstat to AHU S/S)	$25	1	$25	4	4	$50	$200	0.4	$75	$30	$255
setup/programming		1	$0	2	2	$50	$100	0.2	$75	$15	$115
misc. hardware	$50	1	$50	1	1	$50	$50	0.1	$75	$8	$108
Remove existing air compressor and deliver to DoDEA Facility Engineer		0	$0	3	0	$50	$0	0.0	$75	$0	$0
Execute performance verification test (PVT)		1	$0	0.5	0.5	$50	$25	0.1	$75	$4	$29
Provide documentation and training											
design/drafting		1		2	2	$50	$100	4.0	$75	$300	$400
copying/duplication	$100	1	$100	0.1	0.1	$30	$3	0.0	$75	$1	$104
prep for training		1	$0	2	2	$50	$100	0.2	$75	$15	$115
training		1		1	1	$50	$50	0.1	$75	$8	$58
Task Totals:			$1,761		44		$2,203	8		$616	**$4,580**

Task 6. Single zone AHU 10 (Serving the Auditorium)											
Replace pneumatic CHW coil valves/actuators with electric	$425	1	$425	6	6	$50	$300	0.6	$75	$45	$770
Remove pneumatic controllers (and any unused enclosures)		1		5	5	$50	$250	0.5	$75	$38	$288
Install DDC system, including controller, sensors, and cabling											
enclosure	$75	1	$75	2	2	$50	$100	0.2	$75	$15	$190
operator interface display device	$336	1	$336	1	1	$50	$50	0.1	$75	$8	$394
controller	$500	1	$500	8	8	$50	$400	0.8	$75	$60	$960
I/O hardware:											
AI: RAT point sensor	$24	1	$24	0.5	0.5	$50	$25	0.1	$75	$4	$53
AI/DI: Space tstat	$26	1	$26	1	1	$50	$50	0.1	$75	$8	$84
AO: CHW valve		1	$0	0	0	$50	$0	0.0	$75	$0	$0
DI and DO: Fan status & S/S CSR	$75	1	$75	0.5	0.5	$50	$25	0.1	$75	$4	$104
DI: smoke		1	$0	0	0	$50	$0	0.0	$75	$0	$0
sensor/actuator cabling/conduit	$25	5	$125	1.5	7.5	$50	$375	0.8	$75	$56	$556
actuators											
comm. cabling (tstat to AHU S/S)	$25	1	$25	4	4	$50	$200	0.4	$75	$30	$255
setup/programming		1	$0	2	2	$50	$100	0.2	$75	$15	$115
misc. hardware	$50	1	$50	1	1	$50	$50	0.1	$75	$8	$108
Remove existing air compressor and deliver to DoDEA Facility Engineer		0	$0	3	0	$50	$0	0.0	$75	$0	$0
Execute performance verification test (PVT)		1	$0	0.5	0.5	$50	$25	0.1	$75	$4	$29
Provide documentation and training											
design/drafting		1		2	2	$50	$100	4.0	$75	$300	$400
copying/duplication	$100	1	$100	0.1	0.1	$30	$3	0.0	$75	$1	$104
prep for training		1	$0	2	2	$50	$100	0:2	$75	$15	$115
training		1		1	1	$50	$50	0.1	$75	$8	$58
Task Totals:			$1,761		44		$2,203	8		$616	**$4,580**

Task 7. Single zone AHU 11 (Serving the Band room)											
Replace pneumatic CHW coil valves/actuators with electric	$425	1	$425	6	6	$50	$300	0.6	$75	$45	$770
Remove pneumatic controllers (and any unused enclosures)		1		5	5	$50	$250	0.5	$75	$38	$288
Install DDC system, including controller, sensors, and cabling											
enclosure	$75	1	$75	2	2	$50	$100	0.2	$75	$15	$190
operator interface display device	$336	1	$336	1	1	$50	$50	0.1	$75	$8	$394
controller	$500	1	$500	8	8	$50	$400	0.8	$75	$60	$960
I/O hardware:											
AI: RAT point sensor	$24	1	$24	0.5	0.5	$50	$25	0.1	$75	$4	$53
AI/DI: Space tstat	$26	1	$26	1	1	$50	$50	0.1	$75	$8	$84
AO: CHW valve		1	$0	0	0	$50	$0	0.0	$75	$0	$0
DI and DO: Fan status & S/S CSR	$75	1	$75	0.5	0.5	$50	$25	0.1	$75	$4	$104
DI: smoke		1	$0	0	0	$50	$0	0.0	$75	$0	$0
sensor/actuator cabling/conduit	$25	5	$125	1.5	7.5	$50	$375	0.8	$75	$56	$556
actuators											
comm. cabling (tstat to AHU S/S)	$25	1	$25	4	4	$50	$200	0.4	$75	$30	$255
setup/programming		1	$0	2	2	$50	$100	0.2	$75	$15	$115
misc. hardware	$50	1	$50	1	1	$50	$50	0.1	$75	$8	$108
Remove existing air compressor and deliver to DoDEA Facility Engineer		0	$0	3	0	$50	$0	0.0	$75	$0	$0
Execute performance verification test (PVT)		1	$0	0.5	0.5	$50	$25	0.1	$75	$4	$29
Provide documentation and training											
design/drafting		1		2	2	$50	$100	4.0	$75	$300	$400
copying/duplication	$100	1	$100	0.1	0.1	$30	$3	0.0	$75	$1	$104
prep for training		1	$0	2	2	$50	$100	0.2	$75	$15	$115
training		1		1	1	$50	$50	0.1	$75	$8	$58
Task Totals:			$1,761		44		$2,203	8		$616	**$4,580**

Task 8. Single zone AHU 12 (Serving Gym offices)											
Replace pneumatic CHW coil valves/actuators with electric	$425	1	$425	6	6	$50	$300	0.6	$75	$45	$770
Remove pneumatic controllers (and any unused enclosures)		1		5	5	$50	$250	0.5	$75	$38	$288
Install DDC system, including controller, sensors, and cabling											
enclosure	$75	1	$75	2	2	$50	$100	0.2	$75	$15	$190
operator interface display device	$336	1	$336	1	1	$50	$50	0.1	$75	$8	$394
controller	$500	1	$500	8	8	$50	$400	0.8	$75	$60	$960
I/O hardware:											
AI: RAT point sensor	$24	1	$24	0.5	0.5	$50	$25	0.1	$75	$4	$53
AI/DI: Space tstat	$26	1	$26	1	1	$50	$50	0.1	$75	$8	$84
AO: CHW valve		1	$0	0	0	$50	$0	0.0	$75	$0	$0
DI and DO: Fan status & S/S CSR	$75	1	$75	0.5	0.5	$50	$25	0.1	$75	$4	$104
DI: smoke		1	$0	0	0	$50	$0	0.0	$75	$0	$0
sensor/actuator cabling/conduit	$25	5	$125	1.5	7.5	$50	$375	0.8	$75	$56	$556
actuators											
comm. cabling (tstat to AHU S/S)	$25	1	$25	4	4	$50	$200	0.4	$75	$30	$255
setup/programming		1	$0	2	2	$50	$100	0.2	$75	$15	$115
misc. hardware	$50	1	$50	1	1	$50	$50	0.1	$75	$8	$108
Remove existing air compressor and deliver to DoDEA Facility Engineer		1	$0	3	3	$50	$150	0.3	$75	$23	$173
Execute performance verification test (PVT)		1	$0	0.5	0.5	$50	$25	0.1	$75	$4	$29
Provide documentation and training											
design/drafting		1		2	2	$50	$100	4.0	$75	$300	$400
copying/duplication	$100	1	$100	0.1	0.1	$30	$3	0.0	$75	$1	$104
prep for training		1	$0	2	2	$50	$100	0.2	$75	$15	$115
training		1		1	1	$50	$50	0.1	$75	$8	$58
Task Totals:			$1,761		47		$2,353	9		$638	**$4,752**

Task 9. Communications Network											
Install network interface between AHU/VAV controllers and OWS											
enclosure	$75	1	$75	2	2	$50	$100	0.2	$75	$15	$190
modem	$50	1	$50	1	1	$50	$50	0.1	$75	$8	$108
primary control interface unit	$300	1	$300	4	4	$50	$200	0.4	$75	$30	$530
comm. cabling	$1,000	1	$1,000	40	40	$50	$2,000	4.0	$75	$300	$3,300
setup/programming		1	$0	8	8	$50	$400	0.8	$75	$60	$460
misc. hardware	$500	1	$500	2	2	$50	$100	0.2	$75	$15	$615
Install OWS in building 566											
Computer, monitor, modem	$1,500	1	$1,500	8	8	$50	$400	0.8	$75	$60	$1,960
Windows software package	$475	1	$475	0	0	$50	$0	0.0	$75	$0	$475
DDC Configuration software package installed	$800	1	$800	1	1	$50	$50	0.1	$75	$8	$858
DDC GUI software package installed	$1,500	1	$1,500	1	1	$50	$50	0.1	$75	$8	$1,558
Install OWS graphical user interface (GUI) software		1		20	20	$50	$1,000	2.0	$75	$150	$1,150
Execute performance verification test (PVT)		1	$0	4	4	$50	$200	0.4	$75	$30	$230
Provide documentation and training											
design/drafting		1		6	6	$50	$300	18.0	$75	$1,350	$1,650
copying/duplication	$250	1	$250	1	1	$30	$30	0.1	$75	$8	$288
prep for training		1	$0	16	16	$50	$800	1.6	$75	$120	$920
training		1		8	8	$50	$400	0.8	$75	$60	$460
Task Totals:			$6,450		122		$6,080	30		$2,220	**$14,750**

Task 10. Insulate air handlers											
Remove insulation from interior of all AHU fan cabinets	$165	1	$165	20	20	$50	$1,000	2.0	$75	$150	$1,315
Install insulation on exterior of all AHU fan cabinets	$2,200	1	$2,200	44	44	$50	$2,200	4.4	$75	$330	$4,730
Task Totals:			$2,365		64		$3,200	6		$480	**$6,045**

DDC Upgrade Summary	Hardware			Technician			Manager/Engineer			
		total		hrs		labor $	hrs		labor $	Total
Task 1. VAV terminal units 1 thru 34 (In classrooms)		$17,804		496		$24,580	65		$4,830	$47,214
Task 2. VAV AHUs 1,2,4,&5 (Serving classroom units)		$13,800		259		$12,930	33		$2,483	$29,213
Task 3. VAV AHU 8 (Serving Drafting/Graphic arts units)		$3,650		74		$3,703	11		$841	$8,194
Task 4. Single zone AHUs 3 and 6 (Main office & library)		$3,795		85		$4,253	12		$923	$8,971
Task 5. Single zone AHU 7 (Serving the Cafeteria)		$1,761		44		$2,203	8		$616	$4,580
Task 6. Single zone AHU 10 (Serving the Auditorium)		$1,761		44		$2,203	8		$616	$4,580
Task 7. Single zone AHU 11 (Serving the Band room)		$1,761		44		$2,203	8		$616	$4,580
Task 8. Single zone AHU 12 (Serving Gym offices)		$1,761		47		$2,353	9		$638	$4,752
Task 9. Communications Network		$6,450		122		$6,080	30		$2,220	$14,750
Task 10. Insulate air handlers		$2,365		64		$3,200	6		$480	$6,045
Project totals:		**$54,908**		**1280**		**$63,708**	**191**		**$14,262**	**$132,878**
				32	wks		5	wks		

Note: Labor rates are fully loaded (OH and profit)

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14. ABSTRACT

The U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) was requested to independently assess the heating, ventilation, and air-conditioning (HVAC) system and related controls at Antilles High School, Antilles Consolidated School System, Fort Buchanan, Puerto Rico, and to review a recent proposal to replace the Antilles High School HVAC control system.

While the system was found to be well-designed and appropriate for the application, much of the equipment had degraded significantly, especially controller-actuated parts of the equipment. Consequently, the HVAC systems were operated in an "on/off" mode to provide full or no cooling. The study recommended the replacement of the pneumatic control system with a new direct digital control (DDC) system, and replacement of actuated devices, including control valves and inlet guide vanes (the latter with variable speed drives). It was strongly recommended that the system be specified and designed to: (1) ensure compatibility with existing maintenance practices, (2) include such desirable DDC functions as energy management, reporting, alarming, diagnostics, and remote operation, and (3) consider future network expansion to other Department of Defense Education Activity (DoDEA) schools in Puerto Rico.

15. SUBJECT TERMS
operation and maintenance, Fort Buchanan, PR, direct digital control (DDC) system, HVAC systems, HVAC controls

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